

Annual Progress Report for

Grant NAG 5-2346

Titled

GEOTAIL MCA PLASMA WAVE INVESTIGATION
DATA ANALYSIS

Covering the reporting period

August 15, 1995 to August 14, 1996

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by

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This report is for NASA Grant NAG 5-2346, GEOTAIL MCA Plasma Wave Investigation Data Analysis. This report covers the time period August 15, 1995, to August 14, 1996. NASA Grant NAG 5-2346 from Goddard Space Flight Center (GSFC) supports the data reduction and analysis effort at The University of Iowa for the ISTP/GGS GEOTAIL Multi-Channel Analyzer (MCA) which is a part of the GEOTAIL Plasma Wave Instrument (PWI). The International Solar Terrestrial Physics/Global Geospace Science (ISTP/GGS) program began as the Origin of Plasma in the Earth's Neighborhood (OPEN). The goals of the program include identifying, studying, and understanding the source, movement, and dissipation of plasma mass, momentum, and energy between the Sun and the Earth. The GEOTAIL spacecraft was built by the Japanese Institute of Space and Astronautical Science and has provided extensive measurements of entry, storage, acceleration, and transport in the geomagnetic tail. Due to the nature of the GEOTAIL trajectory which kept the spacecraft passing into the deep tail, GEOTAIL also made "magnetopause skimming passes" which allowed measurements in the outer magnetosphere, magnetopause, magnetosheath, bow shock, and upstream solar wind regions as well as in the lobe, magnetosheath, boundary layers, and central plasma sheet regions of the tail. In late 1994, after spending nearly 30 months primarily traversing the deep tail region, GEOTAIL began its near-Earth phase where apogee was reduced first to about 50 Re and later finally to 30 Re and perigee was decreased to about 10 Re. The WIND spacecraft was launched on November 1, 1994, and the POLAR spacecraft was launched on February 24, 1996. These successful launches have dramatically increased the opportunities for GEOTAIL and the GGS spacecraft to be used to conduct the global research for which the ISTP program was designed.

The measurement and study of plasma waves make significant contributions to the ISTP/GGS goals. Plasma waves are involved in the energization and de-energization of plasma and energetic particles via numerous wave-particle interaction processes. These processes are especially evident at various boundaries between the different regions of geospace. Plasma wave emissions can also be used to identify the plasma density as well as the region of space the spacecraft is in or the boundary that is being crossed. The detection of intense low frequency electromagnetic waves is usually indicative of the presence of strong currents. Observations of the low frequency MCA magnetic field data have been used in the regime identification study reported in Eastman et al. [1996]. Plasma wave measurements help identify plasmoids and flux ropes. Observations of Auroral Kilometric Radiation (AKR) and electromagnetic escaping continuum radiation are remote indicators on the timing and strengths of geomagnetic disturbances.

A detailed description of the Plasma Wave Instrument (PWI) experiment and the initial results are contained in Matsumoto et al. [1994]. The United States National Aeronautics and Space Administration (NASA) provided the Multi-Channel Analyzer (MCA) portion of PWI under contract to The University of Iowa for which Dr. Roger R. Anderson is Principal Investigator and U. S. Lead Investigator for the U. S. GEOTAIL MCA Investigation. Dr. Anderson is a Co-Investigator on the GEOTAIL PWI for which Professor Hiroshi Matsumoto of Kyoto University is Principal Investigator. Dr. Anderson has two

Co-Investigators on the U. S. GEOTAIL MCA Investigation: Professor Donald A. Gurnett of The University of Iowa and Dr. William W. L. Taylor of Hughes STX Corporation. It is important to note that the MCA data are quite complementary to the other GEOTAIL PWI data. The MCA provides continuous high-time resolution with broad frequency resolution while the PWI Sweep Frequency Analyzer (SFA) provides high-frequency resolution but coarse time resolution. Another advantage of the MCA is that it measures down to 5 Hz while the SFA begins at 24 Hz. The low frequency range of the MCA has provided an abundant amount of interesting electromagnetic data in the 5 Hz to 20 Hz range not reachable by the SFA. Data from both the MCA and SFA can be used to identify periods from which the PWI WaveForm Capture (WFC) data analysis efforts should be concentrated. The WFC provides both high-time resolution and high-frequency resolution but only for very limited periods.

The Multi-Channel Analyzer (MCA) portion of the GEOTAIL Plasma Wave Instrument has operated perfectly since the GEOTAIL launch on July 24, 1992. The WANT (Wire ANTenna) and PANT (Probe ANTenna) electric antennas were each successfully deployed on August 27, 1992, to their 100 meter tip-to-tip lengths. The MAST antennas for the Flux-gate and Search Coil magnetometers were deployed to their full lengths on September 16, 1992. Nearly continuous low-bit-rate Editor-B tape-recorded data (complete 20-channel Electric and 14-Channel Magnetic spectra every 1/2 second) have been acquired from the MCA since early September, 1992. Approximately eight hours per day of high-bit-rate Editor-A Real Time data (complete Electric and Magnetic spectra every 1/4 second) have also been accumulated since early September 1992. These data sets have included eighteen extensions into the deep-tail region with apogees ranging from around 60 Re to more than 208 Re in the period up to late 1994 when perigee was reduced to 10 Re and apogee first to 50 Re and finally to 30 Re in early 1995. All three types of passes have included several near-Earth magnetopause-skimming perigee passes. Many new interesting phenomena have been detected during these orbits using the high-time-resolution MCA measurements.

Much has been accomplished under Grant NAG 5-2346 for GEOTAIL MCA PLASMA WAVE INVESTIGATION DATA ANALYSIS over the past year. We have maintained and improved programs for plotting the MCA, SFA, and MGF (GEOTAIL Magnetic Field Experiment) data. We have created programs for plotting the cB/E ratios for the 14 channels of the MCA that have both electric and magnetic data. These plots are used to help identify the wave modes being observed. We have revised and improved programs for plotting the orbit data retrieved electronically from the GSFC Central Data Handling Facility (CDHF). We have used the Key Parameter Visualization Tool software provided by the CDHF and the Science Planning and Operations Facility (SPOF) at GSFC to plot Key Parameter data from the CANOPUS instrumentation on a regular basis. Our programmers have also continued to develop programs and provide technical support for the GEOTAIL data analysis efforts of Co-Investigator William W. L. Taylor.

We now plot all the real-time MCA and SFA data we collect in appropriate length color spectrogram plots for each daily pass. All of the SIRIUS data we have received we have

plotted normally in 24-hour plots. Many exciting things have already been observed from our studying these plots and we are continuing detailed collaborations with the other GEOTAIL experiments, other members of the GEOTAIL Plasma Wave Team, as well as experimenters from other spacecraft presently operating including POLAR, WIND, IMP-J, GOES, and Galileo, and from ground observing sites such as the CANOPUS network. We will discuss some of the more interesting observations that we have made this past year using the GEOTAIL MCA and PWI data.

A new type of low frequency (typically tens of kHz) terrestrial radio emission with a smooth time profile and a negative frequency drift was first studied by Steinberg et al. [1988,1990] from ISEE-3 and ISEE-1 observations in the solar wind. The phenomenon was called isotropic terrestrial kilometric radiation (ITKR) because of its characteristics and apparent association with auroral kilometric radiation (AKR). Kaiser et al. [1996] used data from the WAVES experiment on the WIND spacecraft to determine that the emissions also have a bursty high-frequency component which has much less frequency drift and extends up to 500 kHz. They preferred calling the phenomena LF (Low Frequency) bursts due to their similarity to Jovian "type III" bursts and their observation that the bursts often appeared isolated from AKR. All of the data used in their study came from the period November 12, 1994, to July 31, 1995, when WIND was predominantly in the solar wind and upstream from the Earth's bow shock.

Using the list of LF bursts identified by the WIND/WAVES team, we have examined the GEOTAIL Plasma Wave Instrument data for the same time periods. From November 12, 1994, until late February 1995, GEOTAIL mainly traversed the downstream tail region with apogee extending out to about 50 Re. In late February 1995, GEOTAIL was moved into a 10 Re by 30 Re inertial orbit with the initial apogee near dusk and moving towards noon at a rate of two hours of local time per month. Low frequency bursts have been identified in the GEOTAIL data for nearly all of the cases on the WIND/WAVES list. Many additional LF bursts have been identified in the GEOTAIL data prior to the WIND launch and even more have been identified in both the GEOTAIL and WIND data since the time of the original WIND/WAVES study. Many of the bursts displayed the diffuse falling tail characteristic of "type III" bursts. Almost all of the GEOTAIL events were associated with active or enhanced AKR. Frequently the LF bursts would occur among a series of AKR bursts with progressively decreasing and then increasing lower frequency cutoffs. Several LF burst events have been clearly identified with strong isolated substorms detected by the Canopus ground magnetometers. Recently we have found indications of enhanced field aligned currents observed by the GOES 8 magnetometers simultaneously with a strong LF burst event. So far in the GEOTAIL data we have detected low frequency terrestrial "type III" bursts in both the downstream and upstream solar wind, in the magnetosheath, in the lobe, and possibly in the plasma sheet. Details of the spectra and other wave characteristics are being compared with the WIND/WAVES observations to help identify the source mechanism and location as well as the likely propagation paths. Many good examples of LF bursts observed by the two spacecraft at various distances on opposite sides of the Earth have

been observed. The recent launch of POLAR has been important as we are now able to use POLAR to detect the AKR very near the source region.

A LF burst detected around 0545 UT on April 14, 1996, provides an excellent example of the wealth of knowledge the GGS/ISTP armada of spacecraft and ground stations can focus on solar-terrestrial interactions. Our attention was first drawn to this event by the plot of the CANOPUS key parameter CU and CL data that we now plot on a routine basis. CU is the upper trace and CL is the lower trace of the envelope of all magnetograms for the CANOPUS array of ground magnetometers. CU and CL are the CANOPUS equivalent of the AU and AL indexes although it must be noted that the CANOPUS array is not world-wide. In an ongoing study of the CANOPUS correlations with continuum storm events observed in the GEOTAIL PWI data we had fortuitously discovered that LF bursts were usually associated with strong narrow negative bays, many as deep as -800 to -1000 nT. This was in sharp contrast to our findings that the continuum storms were typically associated with modest negative bays of the order of only about -200 to -300 nT.

On April 14, 1996, CL reached a minimum of about -970 nT at 0545 UT. The LF burst was most prominent in the 60 kHz to 100 kHz range of the SFA data beginning about 0540 UT. GEOTAIL was in the solar wind just outside the subsolar bow shock. GEOTAIL's coordinates were GSEX=18.6 Re, GSEY=4.6 RE, GSEZ=-1.5 RE, and R=19.2 Re. Emission lines at the solar wind plasma frequency, F_p , and its second harmonic, $2F_p$, 30 kHz and 60 kHz respectively, were quite prominent. A weak dispersed low frequency portion of the LF burst was evident from about 60 kHz near 0540 UT down to 30 kHz near 0545 UT. Interestingly enough is the fact that the AKR above 100 kHz also showed time dispersion in the opposite sense. The higher-frequency AKR intensification began around 100 kHz at 0540 UT and continued up to 300 kHz at 0545 UT. This prolonged rising feature of the AKR is a new phenomena we are just beginning to study. We believe that the time dispersion for both the high and low frequency portion of the LF bursts may be due to the movement of the AKR source region suggested by analysis of the ground magnetometer data.

A Thermal Noise Receiver (TNR) spectrogram from the WIND/WAVES experiment for the same time period showed the LF burst extending from around 30 kHz up to its upper frequency range of 250 kHz. WIND's coordinates were GSEX=50.5 Re, GSEY=42.3 Re, GSEZ=-4.6 Re, and R=66.1 Re. Being far to the side of the Earth-Sun line, WIND was in a much more favorable position to intercept direct radiation from the AKR source region even though it was farther away. For GEOTAIL, much of the direct radiation from the AKR source region was blocked by the Earth and the dense plasmasphere. A plot of the electric field data from the POLAR PWI Sweep Frequency Receiver provided by POLAR PWI PI Don Gurnett showed that the AKR burst beginning around 0540 UT clearly extended down to 30 kHz and up to over 500 kHz. At 0545 UT POLAR was about 6 Re over the Earth's northern polar region. When POLAR is high over the polar regions, it provides excellent observations of the total AKR spectrum at its origin which can then be compared to the remote observations of GEOTAIL and WIND. Since AKR is believed to be generated

near the local electron cyclotron frequency, the higher the AKR frequency, the lower the altitude where it is generated. The Earth and dense plasmasphere totally block the AKR above 300 kHz from reaching GEOTAIL for this event.

Examination of the CANOPUS ground magnetometer showed that the geomagnetic disturbances had intensifications around 0500 UT and 0520 UT and a huge intensification at 0540 UT. The disturbances at 0540 UT were the most intense and most poleward. This could explain the low frequency time dispersion that we see. If the more poleward excursion also corresponds to the disturbance moving to field lines that extend farther out into the magnetosphere, the local AKR frequency will decrease. The CANOPUS data were provided through the courtesy of Gordon Rostoker who is assisting in their interpretation.

When the above April 14, 1996, examples were shown at the July 2, 1996, GGS/ISTP Science Working Group Meeting, Howard Singer from NOAA's SEC offered to provide us the GOES 8 magnetometer data for this time period as well as other time periods of interest. These data are not yet available on the CDHF as GOES 8 KP data. GOES 8 is located at 75 degrees west longitude. At 0500 UT GOES 8 was at about local midnight. This was when the CANOPUS CL index quickly began to decrease. According to Singer, the GOES 8 Hn data showed an increase in field-aligned currents (FACs) at this time and the Hp data showed a small dipolarization of the field. Also, it was at this time that the data began to show a lot more high frequency structure. This high frequency structure continued until about 0545 UT when the Canopus CL reached its most negative value. Singer noted that Hp maximized about the same time that CL minimized. He surmised that CL was showing the strength of the westward electrojet and Hp decreasing was showing the diversion of the tail current. It suggested that the diverted tail current was feeding the electrojets. It was also during this time that the field-aligned currents were largest and fluctuating. Singer added that there is probably a lot of spatial structure in the FACs that controls what is seen at GOES.

Up to now we have concentrated on LF bursts that have occurred while the CANOPUS network is near midnight. At the Western Pacific Geophysics Meeting in Brisbane, Australia, Gordon Rostoker showed us how to retrieve ground magnetometer data from around the world from the NOAA NGDC site on the World Wide Web. The first case we examined was for the March 5, 1995, event around 2032 UT shown in Figure 1 of Kaiser et al. [1996]. The results were quite fruitful as the magnetogram from Tromsø, Norway, showed a very large deflection in the geomagnetic declination precisely at that time.

R. R. Anderson is leading the study of the multiple spacecraft and ground observations of the global activity that leads to observations of the LF bursts. He is working mainly with Gordon Rostoker on the CANOPUS data, Mike Kaiser and Jean-Louis Bougeret on the WIND/WAVES data, Howard Singer on the NOAA GOES and NGDC data, Don Gurnett on the POLAR data, and Hiroshi Matsumoto and his colleagues in Japan on the GEOTAIL data. Several papers are in progress including one for the Geophysical Research Letters special issue on GEOTAIL and WIND joint studies which will be submitted by September 30, 1996.

Interesting correlations have been found between the observation of continuum storms throughout the Earth's geomagnetic tail by the GEOTAIL PWI and the CANOPUS ground magnetometer data. During the more than four years that GEOTAIL has been in operation, PWI has detected numerous continuum storms in the geomagnetic tail at distances ranging from 10 Re to 210 Re. Data from the CANOPUS ground magnetometer network has frequently shown good correlation of the onset of the continuum storms with either an increasing CU, decreasing CL, or increasing difference (CU-CL) in the CANOPUS Key Parameter data. The best correlations do occur when the CANOPUS chain is near midnight local time. Studying the time differences in the onsets allows us to determine that in some instances the continuum source is near the earth while in other instances the sources may well be near the magnetopause boundary far down the tail. Some of the continuum storms occur near in time to the passage of a plasmoid or flux rope over the spacecraft. Some of the continuum storms exhibit discrete structures indicative of non-local plasma frequency harmonics being their source. We are carefully studying individual station magnetograms in order to understand the relationships of the near earth plasma and its dynamics to the characteristics of the various continuum storms. We have found the somewhat unexpected result that the continuum storms were typically associated with modest negative bays of the order of only about -200 to -300 nT. R. R. Anderson is leading this study with valuable assistance from his GEOTAIL PWI colleagues in Japan and Gordon Rostoker in Canada. A paper on this study is in preparation.

One subject of great interest to scientists trying to understand substorm dynamics is the plasmoid or flux rope. The PWI and MCA observations of plasma waves related to plasmoids and flux ropes are adding much to our understanding of these phenomena. Auroral kilometric radiation (AKR) is frequently detected shortly before, throughout, and following the plasmoid observations. Enhanced AKR has been frequently associated with substorm activity. Electron plasma oscillations (EPO) (also called Langmuir waves) occur nearly continuously in the electric field data prior to the spacecraft moving out of the lobe as a plasmoid passes and after the spacecraft reentered the lobe. The observations of electron plasma oscillations before and after plasmoid observations is a common feature. The expected free energy source for driving Langmuir waves is an electron beam. Weak electrostatic emissions just above the electron cyclotron frequency are also observed just prior to a plasmoid passage.

Varieties of broadband electrostatic noise (BEN) are observed during a plasmoid passage. BEN is usually believed to be enhanced in relation to the increased flows and temperatures encountered. Part of the time during a plasmoid passage the BEN may extend in frequency up to between 5 to 10 kHz while for the remaining time the BEN may extend in frequency only up to from several hundred Hz to nearly a kHz. A common plasmoid feature is BEN with a limited frequency range from a few hundred Hz to a few kHz and both upper and lower cutoff frequencies which is referred to as narrowband electrostatic noise (NEN). Moderately strong BEN extending from about 50 Hz up to between 5 to 10 kHz was detected simultaneously with strong very low frequency electromagnetic emissions in the range of about 5 to 50 Hz. These emissions occurred simultaneously with the ambient magnetic field

abruptly changing directions from tailward to sunward and shortly after the plasma flows began earthward around 100 km/s and the ion and electron temperatures both increased. The strong currents that should exist for such a magnetic field change might well be the source of the electromagnetic waves. The increased plasma flows and particle temperatures would be expected to contribute to the generation of BEN.

During the large northward and then southward swings of the magnetic field in the center of the plasmoid there were much enhanced BEN and low frequency electromagnetic noise. The BEN was nearly continuous and very intense at low frequencies. A low frequency band of electromagnetic noise bursts with peak intensity around 5 Hz was also nearly continuous. Sporadic isolated very low frequency narrowband electromagnetic noise bursts of 10 to 20 seconds' duration and peak frequencies between 5 and 30 Hz were observed prior to and during the main portion of the plasmoid passages. Many of these bursts were well correlated with the high-frequency BEN.

An unusual feature associated with plasmoids consists of bursts of electrostatic noise. These bursts are very strong below a few hundred Hz and extend up in frequency to between 1 to 2 kHz. These bursts were unusual for several reasons. They were quite sporadic, intense, and short-lived. The bursts' amplitude suddenly increased two to three orders of magnitude above background in a fraction of a second. The bursts lasted from about a second up to three or four seconds.

For the many plasmoid and flux-rope events studied, the increased plasma wave activity is well correlated with the increased ion temperatures and flow velocities as well as the plasmoid-like magnetic field structure. Many important questions and research topics have been stimulated by these and other similar observations. The use of AKR observations to identify substorm onsets and plasma wave observations to identify plasmoids continue to be examined. Murata et al. [1995] calculated the sizes of plasmoids and the locations of the near-Earth X-line by using AKR (and a near-Earth satellite when possible) to identify substorm onset (and the release or initiation of the plasmoid flow) and in situ measurements of the magnetic fields from MGF and magnetic noise bursts from the MCA data to determine the timing of the passage of a plasmoid/flux rope over the spacecraft. Eleven events were studied in this initial GRL paper. The addition of more events and the use of additional spacecraft and magnetometer chains to refine or improve the substorm timing is underway to help determine the reliability of these results which are a very important contribution to our improved understanding of substorm dynamics.

R. R. Anderson is the lead author on a paper in preparation which characterizes the plasma waves observed associated with the plasmoid/flux ropes examined in the Frank et al. [1994] paper. The MCA observations discussed above are a part of the plasma wave characteristics paper being prepared. Many studies related to BEN and NEN are in progress. A preliminary paper examining the relation between electrostatic solitary waves and hot plasma flow in the plasma sheet boundary layer has already been published [Kojima et al., 1994]. The possible association of the low frequency electromagnetic waves and the various

electrostatic waves are also being studied. The MCA measurements are especially important for these different studies because they extend to a lower frequency than the other PWI receivers and because they provide much better time resolution than the SFA and much more complete temporal coverage than the WFC.

At a workshop in Kyoto, Japan, in March 1995, GEOTAIL Comprehensive Plasma Instrument investigators L. A. Frank, W. R. Paterson, M. Ashour-Abdalla, and R. R. Anderson met with the rest of the PWI team and several collaborative studies to be carried out between the two experiment teams were outlined.

A paper tentatively titled "Generation Mechanism of Electrostatic Solitary Waves (ESW) Based on GEOTAIL Plasma Wave Observations, Plasma Observations, and Particle Simulation" is in preparation with Hiroshi Matsumoto and Yoshi Omura as lead authors and R. R. Anderson is a co-author. Yoshi Omura visited The University of Iowa in July 1995 and discussed the use of the MCA data to augment the WFC data for this study. We were able to demonstrate that a particular type of ESW identified in the WFC data had identifiable spectral characteristics in our MCA data. This is particularly valuable since the WFC measurements typically cover only 8 seconds every five minutes while the MCA measurements are nearly continuous. The possibility of finding good collaborative particle distribution functions which nominally require 20 seconds was thus greatly expanded. It became possible to identify sufficiently long intervals of various types of ESW in the MCA data to make good comparisons with the particle data. A goal of this paper will be to understand what is responsible for the different types of BEN observed throughout a plasmoid/flux rope event such as discussed earlier.

Hirotsugo Kojima is the lead author on a paper on the observation and generation of Narrowband Electrostatic Noise (NEN). R. R. Anderson is a co-author and has provided high-time resolution MCA color spectrograms for the events being studied. An additional paper on the waveform observations of Broadband Electrostatic Noise (BEN) and NEN with Hirotsugo Kojima as lead author and R. R. Anderson as a co-author was submitted to the Journal of Geophysical Research and presently is being revised. High-time resolution MCA color spectrograms of BEN from the Plasma Sheet Boundary Layer and BEN and NEN from the Magnetosheath were used to compare the spectrum analyzer data with the WFC waveform data.

Isamu Nagano and Satoshi Yagitani from Kanazawa University are the lead authors on a paper studying dayside chorus emissions. R. R. Anderson is a co-author and has provided high-time resolution MCA color spectrograms for the study. In September 1995 Satoshi Yagitani visited The University of Iowa and collaborated with L. A. Frank, W. R. Paterson, and R. R. Anderson on the details of this paper.

L. A. Frank is the lead author on a paper studying the plasmoid/flux rope event occurring around 1740 UT on March 24, 1993. R. R. Anderson is a co-author and will provide a summary of the MCA plasma wave observations.

W. W. L Taylor is leading a morphological study with the goal of imaging the magnetosphere and its tail using plasma waves observed with the GEOTAIL PWI MCA experiment. A statistical study of the multichannel analyzer electric and magnetic field data during the first three years (September 1, 1992, to August 31, 1995) continues. The University of Iowa has provided the programming support for the statistical survey. The results will help the viewer visualize the intensities of the plasma waves throughout the magnetosphere. The primary goal of this study will be to reveal visually the generation and propagation regions of plasma wave emissions throughout the parts of the magnetosphere that GEOTAIL traverses. In addition, this study and similar studies of plasma wave data from spacecraft in complementary orbits will allow techniques to be developed to map plasma densities throughout the magnetosphere using radio sounding. For this study, the magnetosphere was divided into cubical regions varying in size from 2 R_E on a side to 10 R_E on a side, depending on its location in the magnetosphere. GEOTAIL passed through over 2000 of these regions during the three years studied. More than 1.9×10^8 measurements in each of the 34 analyzer channels were made. The number of times each of the 256 possible spectral densities was measured in each of these regions in GSM coordinates was determined for each frequency (electric field - 5.62 Hz to 311 kHz, magnetic field - 5.62 Hz to 10 kHz). This massive statistical data set holds a treasure of information about not only plasma waves, but also about magnetospheric regions and boundaries and the wave-particle interactions that control much of the magnetosphere. Averages of the electric and magnetic field spectral densities were presented at the Fall 1995 AGU meeting. At the Spring 1996 AGU meeting, the medians of the intensities were presented. The figures plotted helped identify the spatial distributions of the plasma wave emissions throughout most of the magnetosphere.

The results of this study will be used to develop techniques to map plasma densities throughout the magnetosphere using radio sounding. In addition, the distribution of the electric and magnetic field spectral densities will be very useful in determining the operational scenarios for radio plasma imaging for the IMAGE space physics mission proposed to NASA as a MDEX project. As an example, continuum radiation may limit, but will certainly not eliminate, the coverage of magnetopause sounding for IMAGE. To determine the extent of this limitation, a joint study of GEOTAIL, POLAR, WIND and CRRES PWI data has just begun. The first periods of interest have been identified and the appropriate investigators have agreed to participate in the study. Dr. Taylor has recently moved from Nichols Research Corporation to Hughes STX Corporation and a new subcontract had to be initiated by The University of Iowa and approved by GSFC. Once this new subcontract is in place he will be able to continue his GEOTAIL research.

At a joint GEOTAIL/WIND workshop held in Honolulu, Hawaii, in May 1995 several new studies were initiated between the experimenters on the GEOTAIL and WIND and IMP-J spacecraft, ground observatories, and theorists, simulators, and modelers. The Low Latitude Boundary Layer group chaired by Terry Onsager and Masato Nakamura solicited data for several events which would be made available to all participants on the World Wide Web. We have provided them with the requested MCA color spectrograms and will participate in the resultant studies. The MCA data in several instances was able to identify

narrow regions of plasma adjacent to the boundary. R. R. Anderson showed examples of the substorm associated continuum storms. While comparing the GEOTAIL PWI data with the WIND WAVES data in order to search for more examples, we were able to discover terrestrial emissions not previously identified. Many other possible studies ranging from plasmoids and magnetic tail configurations to shock and magnetosheath crossings were discussed. The ones which require plasma wave data to aid in their analysis or those which could identify the generation mechanism for waves of interest will be pursued first.

From the above discussion and illustrations it is clear that the vast wealth of data both accumulated and yet to be accumulated from GEOTAIL and the other GGS/ISTP related spacecraft and ground based investigations is extremely valuable for studies ranging from high-time resolution wave-particle interactions to more global boundary studies. These data will provide research opportunities far into the future.

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PRESENTATIONS

The following papers were presented at the Fall Meeting of the American Geophysical Union held in San Francisco, California, in December, 1995.

Correlation of Continuum Storms Observed by the GEOTAIL Plasma Wave Instrument Throughout the Geomagnetic Tail and the CANOPUS Ground Magnetometer Data

R R Anderson, H Matsumoto, D A Gurnett, W W L Taylor, H Kojima, S Kokubun, T Yamamoto, I Nagano, and G Rostoker

Interesting correlations have been found between the observation of continuum storms throughout the Earth's geomagnetic tail by the GEOTAIL Plasma Wave Instrument and the CANOPUS ground magnetometer data. During the more than three years that GEOTAIL has been in operation, the Plasma Wave Instrument has detected numerous continuum storms in the geomagnetic tail at distances ranging from 10 Re to 210 Re. Examination of the CANOPUS ground magnetometer data has frequently shown good correlation of the onset of the continuum storms with either an increasing CU, decreasing CL, or increasing difference (CU-CL) in the CANOPUS Key Parameter data. The best correlations do occur when the CANOPUS chain is near midnight local time. Studying the time differences in the onsets allows us to determine that in some instances the continuum source is near the earth while in other instances the sources may well be near the magnetopause boundary far down the tail. Some of the continuum storms occur near in time to the passage of a plasmoid or flux rope over the spacecraft. Some of the continuum storms exhibit discrete structures indicative of plasma frequency harmonics being their source. We are carefully studying individual station magnetograms in order to understand the relationships of the near earth plasma and its dynamics to the characteristics of the various continuum storms.

Distant Tail View of Averaged AKR Frequency Variation Observed by GEOTAIL/PWI

H. Matsumoto, Y. Kasaba, K. Hashimoto, T. Murata, and R. R. Anderson

GEOTAIL/PWI had observed AKR from distant tail for two years. We present the results of a statistical study on the averaged AKR upper-limit frequency, f_{upper} , and lower-limit frequency, f_{lower} .

We have made a correlation study between the f_{upper} or f_{lower} and deviation angle of s/c from the magnetic equatorial plane, $\theta_{\text{s/c}}$. Both f_{upper} and f_{lower} increase with $|\theta_{\text{s/c}}|$. While $\theta_{\text{s/c}} \sim 0^\circ$ the averaged f_{upper} and f_{lower} are about 400 kHz and 100 kHz, respectively. On the other hand, while $\theta_{\text{s/c}} \sim \pm 30^\circ$ the averaged f_{upper} and f_{lower} rise to about 600 kHz and 200 kHz. Generally AKR high frequency components hardly approach the magnetic equatorial plane because of the plasmopause shielding effect. From the same point of view, the lower frequency components should be affected in the same way, i.e., at $\theta_{\text{s/c}} \sim \pm 30^\circ$ we should have observed lower f_{lower} than at $\theta_{\text{s/c}} \sim 0^\circ$. However, our result is inconsistent with the expectation. These features may suggest to remodel the inner magnetospheric structure.

We also examined correlation with the radial distance of s/c from the Earth, $R_{\text{s/c}}$, and Kp index. (1) f_{upper} and f_{lower} are not correlated with $R_{\text{s/c}}$ beyond $R_{\text{s/c}} \sim 30R_E$. The averaged f_{upper} and f_{lower} are about 500 kHz and 150 kHz, respectively. Within $R_{\text{s/c}} \sim 30R_E$, the f_{upper} and f_{lower} gradually decrease with $R_{\text{s/c}}$. The averaged f_{upper} and f_{lower} are 300 kHz and 100 kHz while $R_{\text{s/c}} \sim 15R_E$. (2) Both f_{upper} and f_{lower} are correlated with Kp index, but in different way. The averaged f_{upper} increases with Kp index, and decreases beyond $Kp \sim 4$. On the other hand, the averaged f_{lower} decreases with Kp index, and correlates little beyond $Kp \sim 4$.

We will also evaluate seasonal variation of the f_{upper} and the f_{lower} .

Characteristics of the Lower-hybrid Wave Occurrence and its Relation with Waves in Higher Frequencies in the Tail

T. Okada, K. Tsuruda, H. Matsumoto, R. Anderson, C. Cattell, and M. Hayakawa

The occurrence of the lower-hybrid (LH) waves at a band of 5-20 Hz is signature of energy transfer between energetic particles and electrostatic waves in the diamagnetic currents in the plasma sheet and plasma sheet boundary layer. Waves are also generated in higher frequencies by the current instabilities. We study the occurrence characteristics of the LH wave using the GEOTAIL Double Probe wave form data, and its relation with the intense waves of short time-duration in the frequency range around 30Hz-1kHz observed by the Plasma Wave Instrument.

Imaging the Magnetosphere and its Tail Using Plasma Waves Observed With GEOTAIL

William W. L. Taylor, Roger R. Anderson, and Hiroshi Matsumoto

GEOTAIL has been collecting plasma wave data almost continuously since shortly after its launch into magnetotail orbits in 1992. A statistical study of the multichannel analyzer electric and magnetic field data during the first three years (September 1992 to August 1995) has begun. This study will reveal visually the generation and propagation regions of plasma wave emissions throughout the parts of the magnetosphere that GEOTAIL traverses. In addition, this study and similar studies of plasma wave data from spacecraft in complementary orbits will allow techniques to be developed to map plasma densities throughout the magnetosphere, using radio sounding.

For this study, the magnetosphere was divided into cubical regions varying in size from $2 R_E$ on a side to $10 R_E$ on a side, depending on its location in the magnetosphere. GEOTAIL passed through over 2000 of these regions during the three years studied. More than 1.9×10^8 measurements in each of the 34 analyzer channels were made. The number of times each of the 256 possible spectral densities was measured in each of these regions in GSM coordinates was determined for each frequency (electric field - 5.62 Hz to 311 kHz, magnetic field - 5.62 Hz to 10 Hz). This massive statistical data set holds a treasure of information about not only plasma waves, but also about magnetospheric regions and boundaries and the wave-particle interactions that control much of the magnetosphere.

As a first step in discovering the meaning in this data set, averages of electric and magnetic field spectral densities will be shown, over all of the GEOTAIL orbit during its first three years. These figures will identify the spatial distributions of the plasma wave emissions throughout most of the magnetosphere.

GEOTAIL and WIND Observation of Discrete Radio Emissions in the Earth's Magnetosphere

Y. Kasaba, H. Matsumoto, R. R. Anderson, J. L. Bougeret, and M. L. Kaiser

We present the results of a study on GEOTAIL/PWI and WIND/WAVES observation of discrete radio emissions. Two types of emissions are investigated. One is discrete emission with a banded structure higher than the local electron plasma frequency f_p . The other is $2f_p$ radio emissions from the terrestrial foreshock region.

GEOTAIL/PWI had observed various faint discrete radio emissions with a banded structure. We classified these emissions into 3 types from frequency characteristics and duration time. (A) : frequency < 100 kHz, and has many rising harmonic components; duration time ~ 0.5 -2 hours. (B) : frequency $<$

100 kHz, and has rising non-harmonic components; duration time \sim a few hours. (C) : frequency < 500 kHz, and has many banded frequency structure with almost constant or gradually rising tone; duration time more than 2 hours. In addition, type A and B are correlated with substorm onset events, while type C is not. We will examine these radiation mechanisms, source locations, and propagation effects with simultaneous WIND/WAVES data.

The $2f_p$ radio emission is produced by the reflected electron beam in the foreshock region upstream of the bow shock. In the foreshock region, we have detected simultaneous sudden frequency changes of the $2f_p$ emission and the local $2f_p$. In some of such events, we observed two simultaneous $2f_p$ emission lines at two different frequencies co-existing for more than ten minutes. Frequencies of each line are stable. This might suggest that there are two regions with different density in the $2f_p$ source near the foreshock region. We will examine these data and evaluate the structure of such double $2f_p$ emissions as well as lifetime of electron beams which radiate these emissions.

GEOTAIL Waveform Observations of the Narrowband Electrostatic Emissions in the Distant Magnetosheath

S. Horiyama, H. Kojima, H. Matsumoto, R. R. Anderson, T. Yamamoto, S. Kokubun, T. Mukai, S. Machida, and Y. Saito

Narrowband electrostatic emissions are commonly observed in the magnetosheath region. We study these electrostatic emissions using the Plasma Wave Instrument onboard the GEOTAIL spacecraft, especially the Wave Form Capture receiver. We found the narrowband electrostatic emissions in the magnetosheath have similar features to those of the Narrowband Electrostatic Noise (NEN) observed in the tail lobe. The features of their waveforms and spectra are summarized as follows: (1) Their waveforms are quasi monochromatic. (2) The frequency of these waves change very quickly. (3) The polarization direction of their electric fields are almost parallel to the ambient magnetic field. (4) The typical bandwidth of their spectra is a few hundreds of Hz. (5) Their central frequency is proportional to the local electron plasma frequency. Another interesting point in the common features of these waves is their good correlation with ion flows along the ambient magnetic field. In the tail lobe region the NEN are observed associated with the cold ion flow along the ambient magnetic field. On the other hand, in the distant magnetosheath where the tailward solar wind flow is observed, the emissions strongly depend on the elevation angle of the ambient magnetic field. They are seen only when the relative angle between the magnetic field and the solar wind flow is small. The common features of these waves suggest their generation mechanisms are similar to each other's. In the present paper, we will introduce the detailed features of the narrowband electrostatic emissions observed in the distant magnetosheath.

We will also discuss their generation mechanisms, referring to the result of computer simulations.

Propagation Analyses of the Electrostatic Solitary Waves observed with the GEOTAIL Spacecraft

H. Kojima, H. Matsumoto, S. Horiyama, R. R. Anderson, T. Yamamoto, S. Kokubun, T. Mukai, S. Machida, and Y. Saito

The Plasma Wave Instrument (PWI) onboard the GEOTAIL spacecraft revealed the waveforms of the Broadband Electrostatic Noise (BEN) observed in the plasma sheet boundary. Their waveforms consist of a series of the isolated bi-polar pulses. After the waveforms, they are termed as "Electrostatic Solitary Waves (ESW)." Further, computer experiments demonstrated that such isolated potentials of the BGK mode can be formed as the results of the nonlinear evolution of the electron beam instabilities. Since the computer simulations predict that the formed ESW potentials should propagate in the same direction with the electron beam as the free energy source, it is very important to analyze the propagation direction of the observed ESW. In general, it is difficult to claim the propagation direction of the purely electrostatic waves, however, in the case of the ESW, we can find it out by comparing the spin dependence of the ESW waveforms with the polarities of the electric field antennas, if we assume that the ESW potential is formed by the electron velocity space vortices of the BGK mode as predicted from the computer experiments. In the present paper, we show that we can detect the propagation direction of the ESW observed in the plasma sheet boundary using the above method and that they change their propagation directions in the short time period which is much shorter than the time resolution of the plasma measurement. This quick change of the ESW propagation direction means that the direction of the electron beam also changes in a short time period. We will discuss the possibility of the quick change of the direction of the electron beam as well as the possible detection of the ESW source regions, using the propagation analyses of the ESW observed in the plasma sheet boundary.

Generation and Propagation of Chorus Emissions Observed by GEOTAIL in the Dayside Outer Magnetosphere

S. Yagitani, I. Nagano, X. Y. Wu, H. Matsumoto, Y. Omura, W. R. Paterson, L. A. Frank, and R. R. Anderson

Many chorus emissions have been observed by the GEOTAIL spacecraft mainly in the dayside outer magnetosphere. Wave forms of two electric and three magnetic fields acquired by the wave form capture (WFC) receiver for 8.7 sec every five minutes give information on a detailed time-frequency behavior of

amplitudes, k-vectors, and Poynting flux of the chorus emissions. Such propagation characteristics are statistically analyzed for rising, falling, hook, and structureless elements of the emissions observed by GEOTAIL, as well as estimation of their generation regions via ray-tracing calculations.

On the other hand, it is very valuable to know particle profiles simultaneously observed with wave data, in order to quantitatively investigate generation mechanisms of chorus emissions through wave-particle interactions. We will present a detailed comparison between < 30 keV electron data observed by the comprehensive plasma instrument (CPI) and chorus frequency-time behavior obtained from the WFC observations, and discuss comprehensively generation and propagation mechanisms of chorus emissions in the dayside outer magnetosphere.

The following papers were presented at the Spring Meeting of the American Geophysical Union held in Baltimore, Maryland, in May 1996.

Low Frequency Terrestrial "Type III" Bursts Observed Simultaneously by GEOTAIL and WIND

Roger R. Anderson, Hiroshi Matsumoto, Kozo Hashimoto, Hirotsugu Kojima, Yasumasa Kasaba, Michael L. Kaiser, Gordon Rostoker, Jean-Louis Bougeret, Jean-Louis Steinberg, and Isamu Nagano

A new type of low frequency (typically tens of kHz) terrestrial radio emission with a smooth time profile and a negative frequency drift was first studied by Steinberg et al. [1,2] from ISEE-3 and ISEE-1 observations in the solar wind. The phenomenon was called isotropic terrestrial kilometric radiation (ITKR) because of its characteristics and apparent association with auroral kilometric radiation (AKR). Kaiser et al. [3] used data from the WIND WAVES experiment to determine that the emissions also have a bursty high-frequency component which has much less frequency drift and extends up to 500 kHz. They preferred calling the phenomena LF (Low Frequency) bursts due to their similarity to Jovian "type III" bursts and their observation that the bursts often appeared isolated from AKR. All of the data used in their study came from the period November 12, 1994, to July 31, 1995, when WIND was predominantly in the solar wind and upstream from the Earth's bow shock. Using the list of LF bursts identified by the WIND/WAVES team, we first examined the GEOTAIL Plasma Wave Instrument (PWI) data for the same time periods. From November 12, 1994, until late February 1995, GEOTAIL mainly traversed the downstream tail region with apogee extending out to about 50 Re. In late February 1995, GEOTAIL was moved into a 10 Re by 30 Re orbit with the initial apogee near dusk and moving towards noon at a rate of two hours of local time per month. Low frequency bursts have been identified in the GEOTAIL data for nearly all of the cases on the WAVES list. Many of the bursts displayed the diffuse falling

tail characteristic of "type III" bursts. Almost all of the GEOTAIL events were associated with active or enhanced AKR. Frequently the LF bursts occurred among a series of AKR bursts with progressively decreasing and then increasing lower frequency cutoffs. Many of the LF burst events have been identified with strong isolated substorms detected by the CANOPUS ground magnetometers. We are continuing to examine the current GEOTAIL PWI, WIND WAVES and CANOPUS data to identify and study additional events. So far in the GEOTAIL data we have detected low frequency terrestrial "type III" bursts in both the downstream and upstream solar wind, in the magnetosheath, in the lobe, and possibly in the plasma sheet. Details of the spectra and other wave characteristics are being compared with the WIND observations to identify the source mechanism and location and the likely propagation paths. Many examples of LF bursts observed by the two spacecraft at various distances on opposite sides of the Earth have been observed. With the CANOPUS data we are studying the characteristics of geomagnetic substorms associated with the unusual plasma wave features.

References

- [1] J.-L. Steinberg et al., Geophys. Res. Lett., **15**, pp 176-179, 1988.
- [2] J.-L. Steinberg et al., Ann. Geophysicae, **8**, pp 671-686, 1990.
- [3] M. L. Kaiser et al., "LF Band Terrestrial Radio Bursts Observed by Wind/WAVES", Geophys. Res. Lett., **23**, in press, 1996.

Imaging the Magnetosphere and its Tail Using Plasma Waves Observed with GEOTAIL and Future Missions

William W. L. Taylor, Roger R. Anderson, and Hiroshi Matsumoto

Since 1992, GEOTAIL has been collecting plasma wave data almost continuously. A statistical study of the multichannel analyzer electric and magnetic field data during the first three years (September 1992 to August 1995) continues. The results help the viewer visualize the intensities of the plasma waves throughout the magnetosphere. In the results presented here, the medians of the intensities will be shown. These results will be used to allow techniques to be developed to map plasma densities throughout the magnetosphere, using radio sounding.

The magnetosphere was divided into cubical regions varying in size from $2 R_E$ on a side to $10 R_E$ on a side, depending on its location in the magnetosphere. GEOTAIL passed through almost 3000 of these regions during its first three years. More than 1.9×10^8 measurements in each of the 34 analyzer channels were made. The number of times each of the 256 possible spectral densities was measured in each of these regions in GSM coordinates was determined for each frequency (electric field - 5.62 Hz to 311 kHz, magnetic field - 5.62 Hz to 10 kHz). This massive statistical data set holds a treasure of information about not

only plasma waves, but also about magnetospheric regions and boundaries and the wave-particle interactions that control much of the magnetosphere.

The medians of the electric and magnetic field spectral densities shown here will be very useful in determining the operational scenarios for radio plasma imaging for the IMAGE spacecraft, proposed to NASA as a MIDEX project.

The following paper was presented at the Western Pacific Geophysics Meeting of the American Geophysical Union held in Brisbane, Australia, in July 1996.

Terrestrial Plasma Wave and Radio Emissions Observed Simultaneously by GEOTAIL and WIND

Roger R. Anderson, Hiroshi Matsumoto, Kozo Hashimoto, Hirotsugu Kojima, Yasumasa Kasaba, Michael Kaiser, Gordon Rostoker, Jean-Louis Bougeret, Jean-Louis Steinberg, and Isamu Nagano

A number of very interesting plasma wave radio emissions of terrestrial origin have been simultaneously observed by both the GEOTAIL Plasma Wave Instrument and the WIND WAVES experiment. Since its launch in November 1994, WIND has made several passes out to the L1 point around 200 Re in front of the earth. During this period Geotail has been primarily in a near-tail highly elliptical 10 Re by 50 Re orbit before late February of 1995 and 10 Re by 30 Re orbit after that. The most unique wave phenomenon is low frequency (typically tens of kHz) terrestrial radio emission with a smooth time profile and a negative frequency drift first studied by Steinberg et al. [1,2] from ISEE-3 and ISEE-1 observations in the solar wind. The phenomenon was called isotropic terrestrial kilometric radiation (ITKR) because of its characteristics and apparent association with auroral kilometric radiation (AKR). Kaiser et al. [3] used data from the WIND WAVES experiment to determine that the emissions also have a bursty high-frequency component which has much less frequency drift and extends up to 500 kHz. They preferred calling the phenomena LF (Low Frequency) bursts due to their similarity to Jovian "type III" bursts and their observation that the bursts often appeared isolated from AKR. Low frequency bursts have been identified in the GEOTAIL data for nearly all of the times they have been observed by WAVES. Many of the bursts display the diffuse falling tail characteristic of "type III" bursts. Almost all of the GEOTAIL events are associated with active or enhanced AKR. Frequently the LF bursts occur among a series of AKR bursts with progressively decreasing and then increasing lower frequency cutoffs. The "continuum storm" wave phenomena first identified by Filbert and Kellogg are observed throughout much of GEOTAIL's orbit but on WIND only when it is fairly close to the earth. The various emissions are found to be associated with different features in the CANOPUS ground magnetometer data. Many of the LF burst events have been identified with strong isolated substorms detected by the CANOPUS ground magnetometers. The "continuum storm" events tend to be

associated with only modest (~ 250 nT) negative bay features. We are continuing to examine the current GEOTAIL PWI, WIND WAVES and CANOPUS data to identify and study additional events. So far in the GEOTAIL data we have detected low frequency terrestrial "type III" bursts in both the downstream and upstream solar wind, in the magnetosheath, in the lobe, and possibly in the plasma sheet. Details of the spectra and other wave characteristics are being compared with the WIND observations to identify the source mechanism and location and the likely propagation paths. Many examples of LF bursts observed by the two spacecraft at various distances on opposite sides of the Earth have been observed. In one very clear example, both WIND at $X = +200$ Re and GEOTAIL at $X = +8$ Re and $Y = +24$ Re observe the LF bursts but only GEOTAIL observes the strong AKR associated with the bursts. With the CANOPUS data we are studying the characteristics of geomagnetic substorms associated with the wave features.

References

- [1] J.-L. Steinberg et al., Geophys. Res. Lett., **15**, pp 176-179, 1988.
- [2] J.-L. Steinberg et al., Ann. Geophysicae, **8**, pp 671-686, 1990.
- [3] M. L. Kaiser et al, "LF Band Terrestrial Radio Bursts Observed by Wind/WAVES", Geophys. Res. Lett., **23**, in press, 1996.

In November, 1995, R. R. Anderson presented a seminar to the Center for Space Physics at Boston University on the GEOTAIL Plasma Wave Instrument journey through the Earth's geomagnetic tail. In February, 1996, R. R. Anderson was the guest speaker at the Oxford, Iowa, Father and Son Banquet and spoke on space physics research and The University of Iowa. The latest important discoveries from GEOTAIL were discussed. In August, 1996, R. R. Anderson presented a seminar to the Physics Department of Newcastle University in Australia on the latest results from the GEOTAIL mission.

PUBLICATIONS

The journal citation, title, author list and abstract of the publications related to the GEOTAIL MCA investigation are listed below.

The following paper was published in Journal of Geomagnetism and Geoelectricity, Vol. **46**, pp 59-95, 1994.

Plasma Wave Observations with GEOTAIL Spacecraft.

H. Matsumoto, I. Nagano, R. R. Anderson, H. Kojima, K. Hashimoto, M. Tsutsui, T. Okada, I. Kimura, Y. Omura, and M. Okada

Abstract. The main scientific objectives of GEOTAIL Plasma Wave Instrument (PWI) are to investigate the characteristic features of wave phenomena which are

generated by a variety of plasma processes occurring within the Earth's magnetosphere.

The PWI measures plasma waves in the frequency range from 5.62 Hz to 800 kHz for the electric components and from 5.62 Hz to 12.5 kHz for the magnetic components. The instrument is composed of three distinct sets of receivers: (1) the Sweep Frequency Analyzer (SFA), (2) the Multi-Channel Analyzer (MCA) and (3) the Wave-Form Capture (WFC). The first two receivers are dedicated to wave spectra measurement, while the last one is used to capture actual waveforms of two electric and three magnetic field components for the measured plasma wave emissions.

The present paper describes the PWI subsystems and their functions. We also report some results from initial observations made during the traversal of the geomagnetic tail and a skimming pass of the dayside magnetopause. These observational results are useful in providing a good overview of the PWI capabilities as well as elucidating the characteristic features of the wave spectra in these regions.

The following paper was published in Geophysical Research Letters, Vol. 21, No. 25, pages 2919-2922, December 15, 1994.

Relation Between Electrostatic Solitary Waves and Hot Plasma Flow in the Plasma Sheet Boundary Layer: GEOTAIL Observations

H. Kojima, H. Matsumoto, T. Miyatake, I. Nagano, A. Fujita, L. A. Frank, T. Mukai, W. R. Paterson, Y. Saito, S. Machida, and R. R. Anderson

Abstract. Most of the BEN wave forms observed by GEOTAIL in the Plasma Sheet Boundary Layer (PSBL) appear as a series of isolated spiky pulses which are termed "Electrostatic Solitary Waves (ESW)." Comparison between the BEN observations and plasma measurements shows that the uppermost frequency of the ESW is closely related to the temperature of the flowing ions in the PSBL. We also find that the observed spike width of the ESW and the inter-pulse time-span change very rapidly on time scales ranging from a few milliseconds to a few hundreds of milliseconds, suggesting that the speed of the ESW potential changes very rapidly.

The following paper was published in Geophysical Research Letters, Vol. 22, No. 14, pages 1849-1852, July 15, 1995.

Estimation of tail reconnection lines by AKR onsets and plasmoid entries observed with GEOTAIL spacecraft

Takeshi Murata, Hiroshi Matsumoto, Hirotugu Kojima, Atsushi Fujita, Tsugunobu Nagai, Tatsundo Yamamoto, and Roger R. Anderson

Abstract. We estimate the location of the reconnection line and plasmoid size in the geomagnetic tail using data from the Plasma Wave Instrument onboard the GEOTAIL spacecraft. We first compare AKR onset events with high energy particle observations at geosynchronous orbit. We determine the plasmoid ejection (reconnection) time by the AKR enhancement only when it corresponds to energetic particle enhancement within five minutes. The traveling time of the plasmoid from the X-line to the spacecraft is calculated by the difference in time of the AKR onset and that of the plasmoid encounter with GEOTAIL. Assuming the plasmoid propagates with the Alfvén velocity in the tail lobe as MHD simulations predict, we estimate the location of the reconnection line in 11 events. The results show that the most probable location of the plasmoid edge is distributed around $x = -60$ Re in GSE coordinates. The estimated size of the plasmoids ranges from 10 to 50 Re in the x direction. If we apply this result to the alternative plasmoid model in which the evolution of the tearing instability causes the generation of plasmoids, the X-line should be approximately at $x = -35$ Re.

The following paper has been submitted to the Journal of Geophysical Research and is presently being revised in the editorial process.

Geotail Waveform Observations of Broadband/Narrowband Electrostatic Noise in the Distant Tail

H. Kojima, H. Matsumoto, S. Chikuba, S. Horiyama, M. Ashour-Abdalla, and R. R. Anderson

Abstract. Broadband Electrostatic Noise (BEN) and Narrowband Electrostatic Noise (NEN) are common wave activities in the plasma sheet boundary and the tail lobe regions, respectively. The similar wave emissions can be observed in the magnetosheath region. We demonstrate the natures of these waves based on the waveform observations by the Plasma Wave Instrument (PWI) onboard GEOTAIL spacecraft. The above observed emissions are divided into the two types of classifications. The BEN type emissions observed in the plasma sheet boundary and magnetosheath consist of series of the isolated bipolar pulses. They are termed after their waveforms as 'Plasma Sheet Boundary Layer Electrostatic Waves (PSBL ESW)' and 'Magnetosheath Electrostatic Solitary Waves (MS ESW).' On the other hand, the waveforms of the NEN type emissions are quasi-monochromatic. They are termed as 'Lobe Electrostatic Quasi-Monochromatic Waves (Lobe EQMW)' and 'Magnetosheath Electrostatic Quasi-Monochromatic Waves (MS EQMW).' The waveform observations with the high time resolution show that one of the common features of these waves is the burstiness. The burstiness means that their amplitudes or frequencies rapidly change in the order of a few milliseconds to a few hundreds of milliseconds. Further, we show that the PSBL ESW, Lobe EQMW, and MS EQMW at least

are the parallel propagating waves relative to the ambient magnetic field, from their spin dependence. The similarities of the ESW and EQMW in the magnetosheath and magnetotail suggest the possibility that these waves are generated in the same generation mechanism.

The following paper will be submitted to the Journal of Geophysical Research in September 1996.

Identification of Magnetospheric Plasma Regimes from the Geotail Spacecraft

T. E. Eastman, S. P. Christon, D. J. Williams, A. T. Y. Lui, R. W. McEntire, E. C. Roelof, T. Doke, L. A. Frank, W. R. Paterson, S. Kokubun, H. Matsumoto, H. Kojima, R. R. Anderson, T. Mukai, Y. Saito, T. Yamamoto, and K. Tsurada

For many important scientific objectives, the analysis and interpretation of magnetospheric data sets require a sorting by primary plasma regimes. This sorting process is much more difficult in the distant magnetotail than for data sets sampled close to Earth. We have carried out systematic regime identifications for most of the deep-tail portion of Geotail data at time scales down to about one minute. Criteria were developed for selection of five basic plasma regimes: plasma sheet, lobe, magnetospheric boundary layer, magnetosheath, and solar wind. Although low-energy plasma data is central to the identification process, critical supplementary information derives from magnetic field and plasma wave data. Our plasma regime identifications provide a critical baseline for efforts towards automated identification. As a first application, data from the Energetic Particle and Ion Composition (EPIC) instrument, filtered according to our plasma regime identifications, have revealed new and important systematic effects in energetic ion spectra, composition, and anisotropy, including statistical correlations that are substantially masked with less effective filters, such as sorting by radial distance. Our identifications provide a key resource for both Goodwill data analysis and interpretation and correlative studies between the Geotail and other ISTP mission data sets.

Respectfully Submitted,



Roger R. Anderson